360 ALPHA

FANS: Fuzzing Android Native System Services via Automated Interface Analysis

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Background

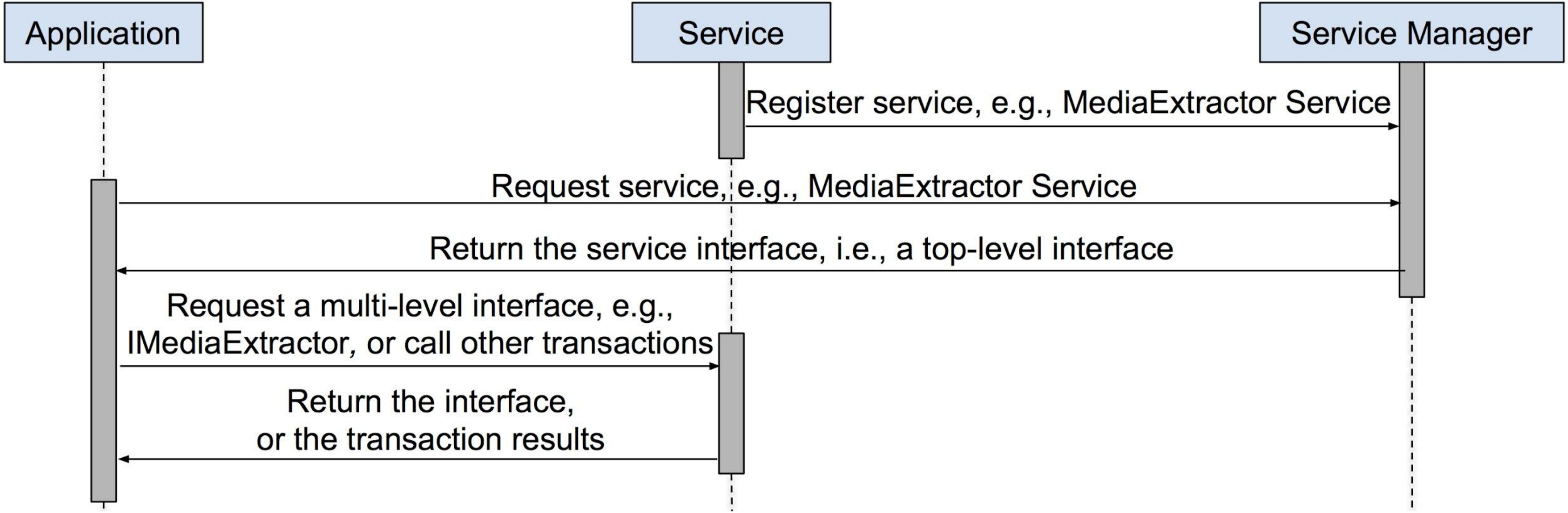
- ❑ Android native system services provide many fundamental functionalities
- ❑ Meanwhile, they are **attractive to attackers**
- ❑ However, to the best of our knowledge, **existing researches paid little attention to them**

Related work

- ❑ Gong[1] mainly finds system services vulnerabilities **manually**
- ❑ BinderCracker[2] captures the input model through **app traffic**
  - ❑ Fuzz system services by mutating the traffic
- ❑ Chizpurfle[3] focuses on the vendor-implemented **Java services**

[1] Guang Gong. Fuzzing android system services by binder call to escalate privilege. BlackHat USA, 2015.
[2] Huan Feng and Kang G. Shin. Understanding and defending the Binder attack surface in Android. ACSAC, 2016.
[3] Antonio Ken Iannillo, et al. Chizpurfle: A Gray-Box Android Fuzzer for Vendor Service Customizations. ISSRE, 2017.

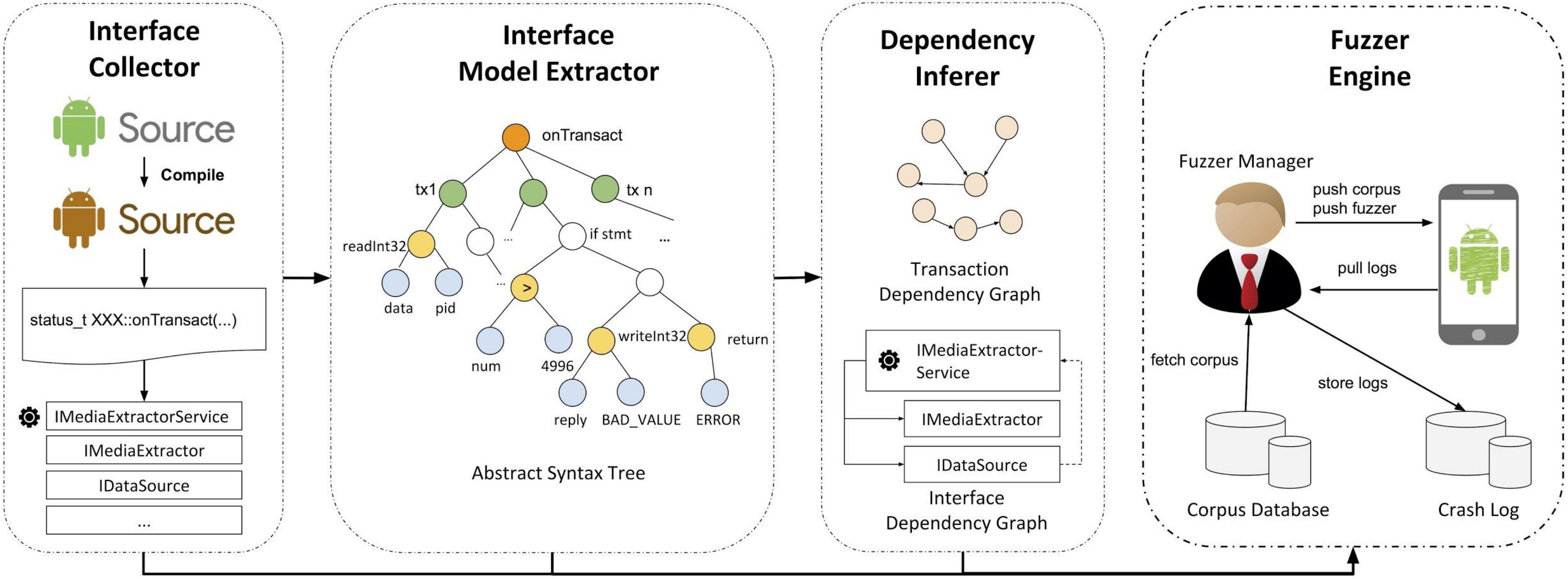
Application-Service Communication Model


Application
Service
Service Manager
Register service, e.g., MediaExtractor Service
Request service, e.g., MediaExtractor Service
Return the service interface, i.e., a top-level interface
Request a multi-level interface, e.g., IMediaExtractor, or call other transactions
Return the interface, or the transaction results

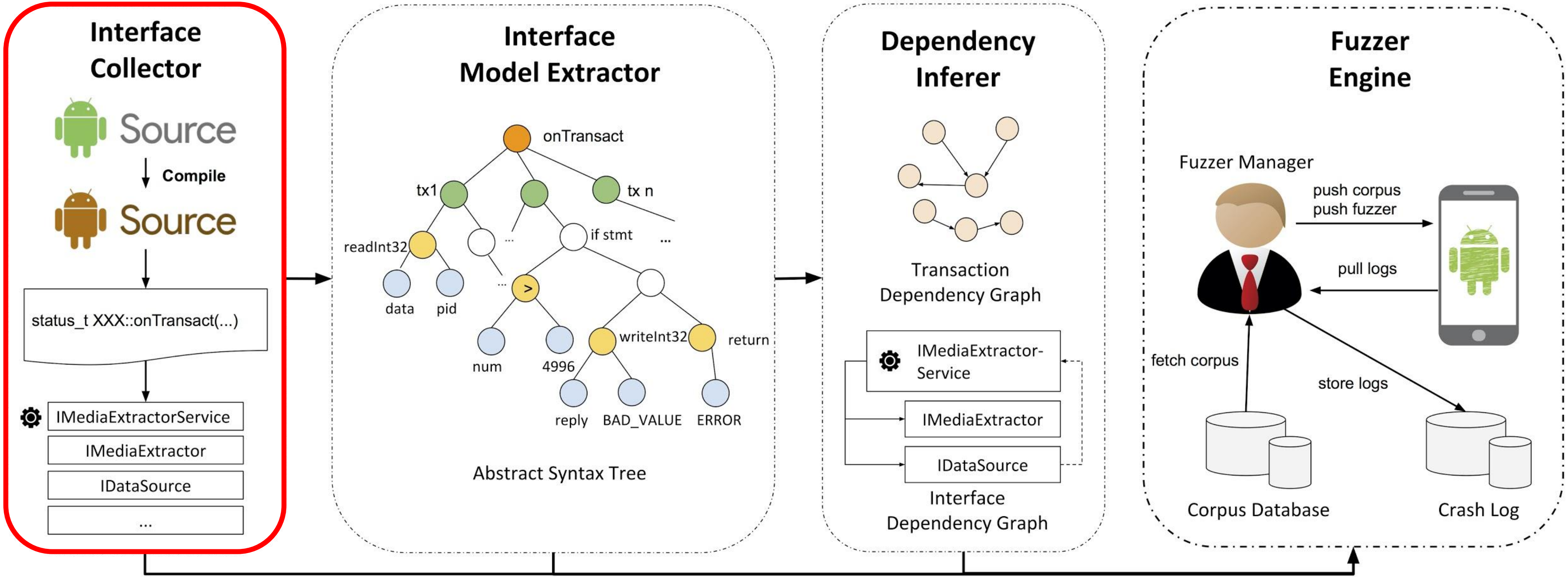
Challenges

- ❏ **C1. Multi-Level Interface Recognition**
  - ❏ Collect all Interfaces
  - ❏ Identify multi-level interfaces
- ❏ **C2. Interface Model Extraction**
  - ❏ Collect all of the possible transactions
  - ❏ Extract the input and output variables in the transactions
- ❏ **C3. Semantically-correct Input Generation**
  - ❏ Variable name and variable type
  - ❏ Variable dependency
  - ❏ Interface dependency

Overview


Interface Collector
Source
Compile
Source
status_t XXX::onTransact(...)
IMediaExtractorService
IMediaExtractor
IDataSource
...
Interface Model Extractor
onTransact
tx1
tx n
readInt32
...
if stmt
...
data
pid
...
>
num
4996
writeInt32
return
reply
BAD_VALUE
ERROR
Abstract Syntax Tree
Dependency Inferer
Transaction Dependency Graph
IMediaExtractor-Service
IMediaExtractor
IDataSource
Interface Dependency Graph
Fuzzer Engine
Fuzzer Manager
push corpus
push fuzzer
pull logs
fetch corpus
store logs
Corpus Database
Crash Log

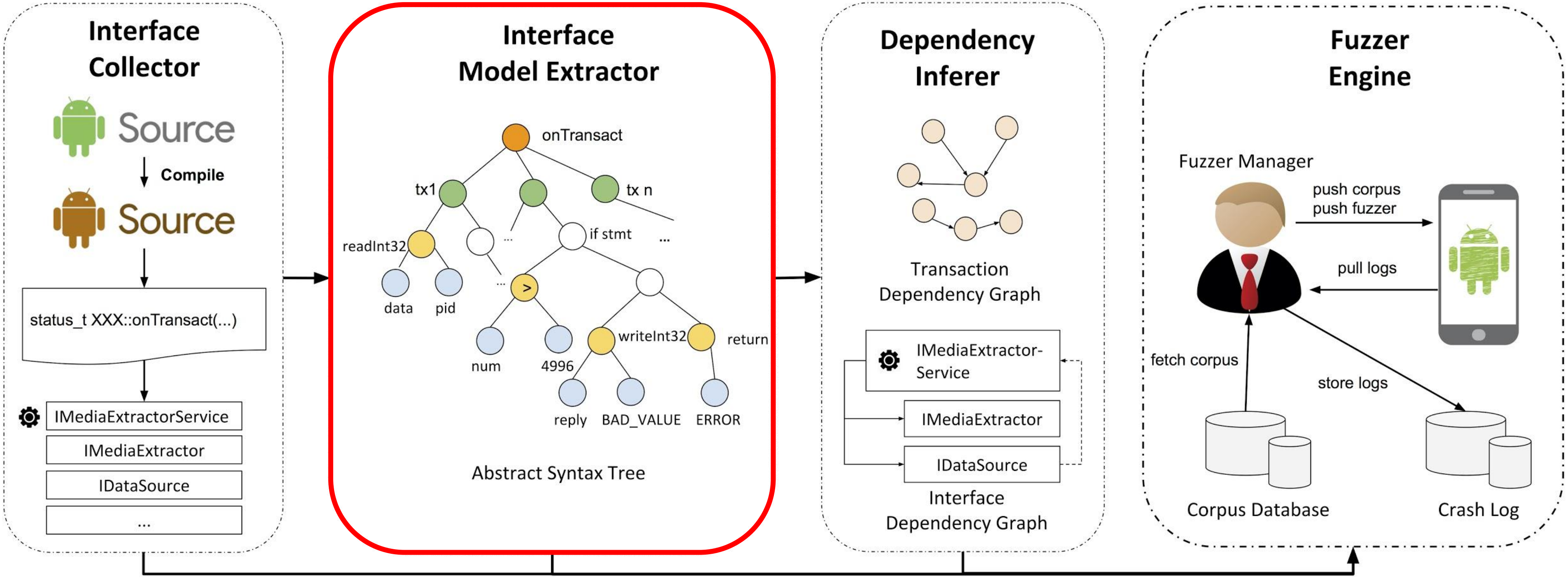
Interface Collector



Interface Collector

- Interface feature
  - Services use **onTransact** method to dispatch transactions
- Collection approach
  - Compile AOSP and record compilation commands
    - During compilation, interface-related files will be used
  - Scan every C++ source file in compilation commands
    - Seek for those files which contain the onTransact pattern

Interface Model Extractor



Transaction Code Identification

- Services use onTransact method to dispatch transactions
  - This process is usually implemented as **a switch statement**
- Identification Solution
  - Identify all transactions of a target interface by **analyzing case nodes** in the abstract syntax tree

Input and Output Variable Extraction

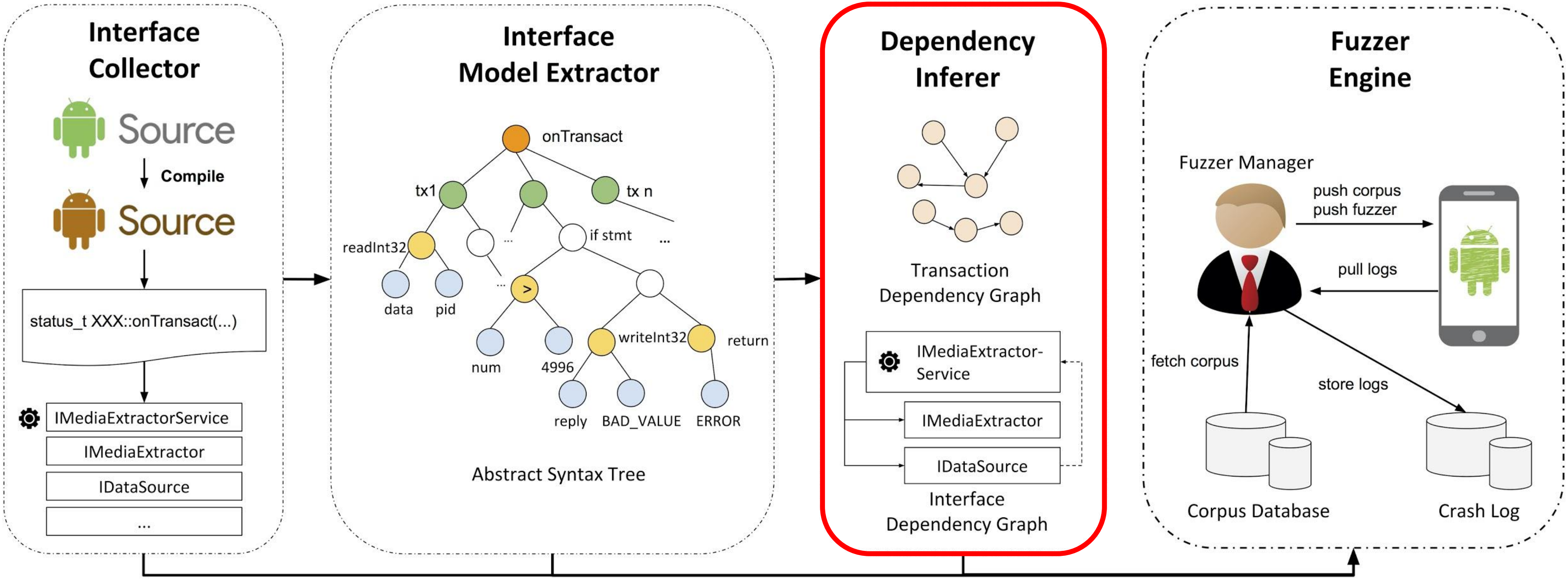
- System services utilize **special methods (e.g., readInt32, writeInt32)** to deal with input and output variables
- Extract I/O variables through recognizing such methods
  - **Variable pattern**
    - Variables might locate in sequential / conditional / loop statements
    - Sequential pattern, conditional pattern, loop pattern
  - **Variable name**
  - **Variable type**

For more details, please refer to the paper.

Auxiliary Information Extraction

- **Transaction paths**
  - Separated by the return statement
- **Extract type definition**
  - Structure and union definition
  - Enumeration definition
  - Type alias

Dependency Inferer



Interface Dependency

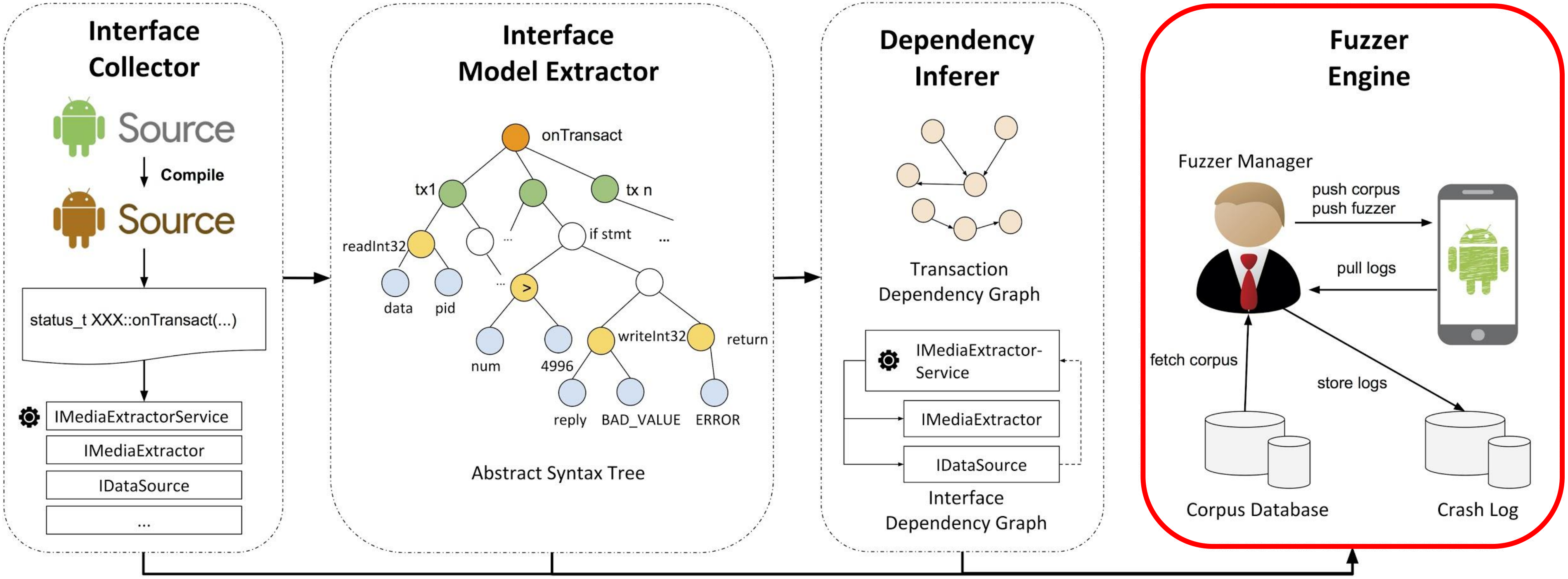
- **Generation dependency**
  - writeStrongBinder method
- **Use dependency**
  - readStrongBinder method

```
/* The following code is in IMediaExtractorService.cpp. */
// generation dependency
sp<IDataSource> source = makeIDataSource(fd, offset, length);
reply->writeStrongBinder(IInterface::asBinder(source));
// use dependency
status_t ret = data.readStrongBinder(&b);
...
sp<IDataSource> source = interface_cast<IDataSource>(b);
```

Variable Dependency

- **Intra-transaction dependency, e.g., conditional dependency**
  - It can be inferred when extracting the interface model
- **Inter-transaction dependency, inference principles:**
  - One variable is input, and the other is output
  - These two variables are located in different transactions
  - Input variable’s type is equal to the output variable’s type
  - Either the input variable type is complex, or the input variable name and the output variable name are similar

Fuzzer Engine

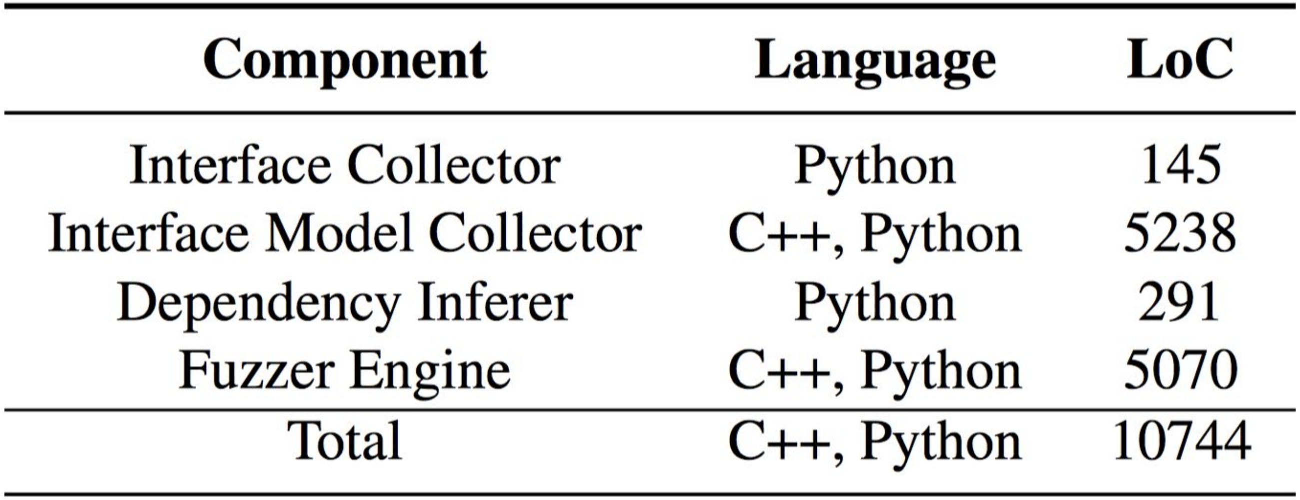


Fuzzer Engine

- **Fuzzer**
  - Randomly generate a transaction
  - Generate the corresponding interface
  - Invoke the target transaction
- **Fuzzer manager**
  - Run fuzzer
  - Monitor fuzzer’s status and restart fuzzer when finding it exited
  - Synchronize logs from mobile to host

Implementation

- Language: C++, Python
- LoC: more than 10,000 lines



Component	Language	LoC
Interface Collector	Python	145
Interface Model Collector	C++, Python	5238
Dependency Inferer	Python	291
Fuzzer Engine	C++, Python	5070
Total	C++, Python	10744

Evaluation

❑ Q1. How many interfaces have been found? What is the relationship between them?

❑ Q2. What does the extracted interface model look like? Is the model complete and precise?

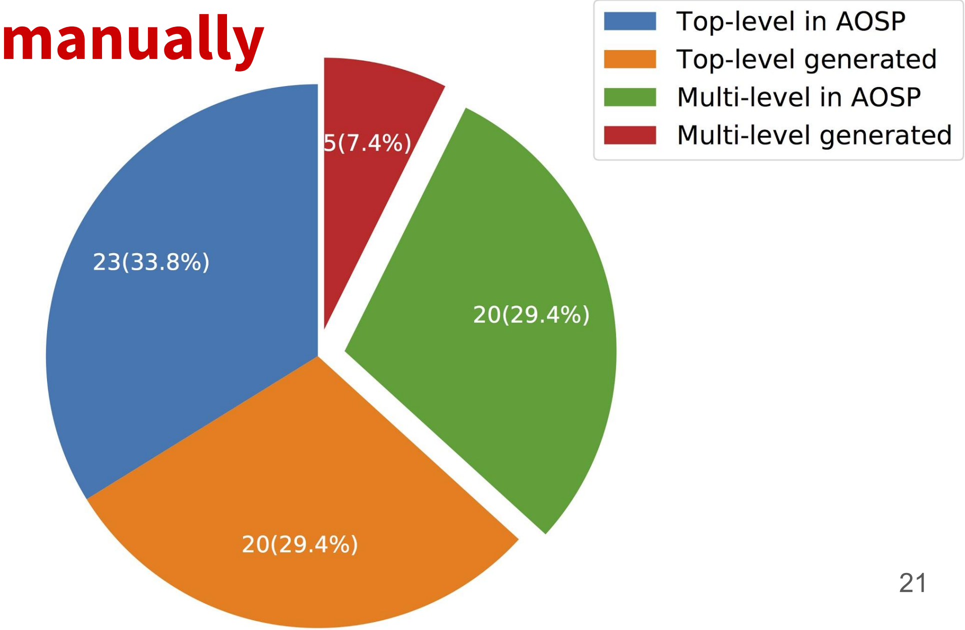
❑ Q3. How effective is FANS in discovering vulnerabilities of Android native system services?

Environment

- Host
  - Ubuntu 18.04, i9-9900K CPU, 32GB memory, 2.5T SSD
- Mobile Phone
  - 1 Pixel, 4 Pixel 2 XLs, 1 Pixel 3 XL
- **Android version: android-9.0.0_r46**
  - The source code can be different for different Pixel models
  - We answer the Q1 and Q2 through the experiment results carried out on Pixel 2 XL

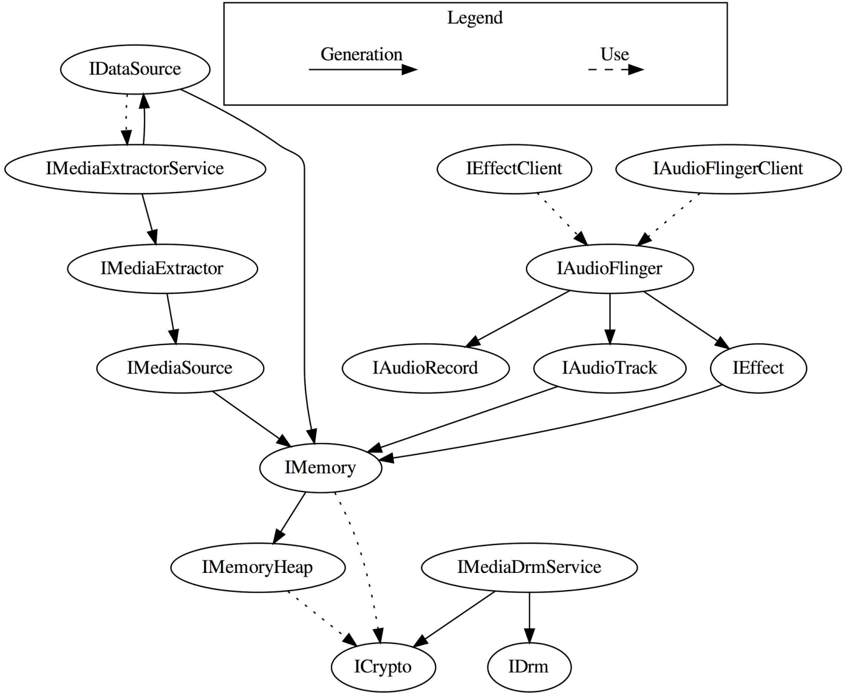
Q1 - Interface Statistics

- ❑ 43 top-level interfaces
- ❑ 25 multi-level interfaces
- ❑ **Most interfaces are written manually**



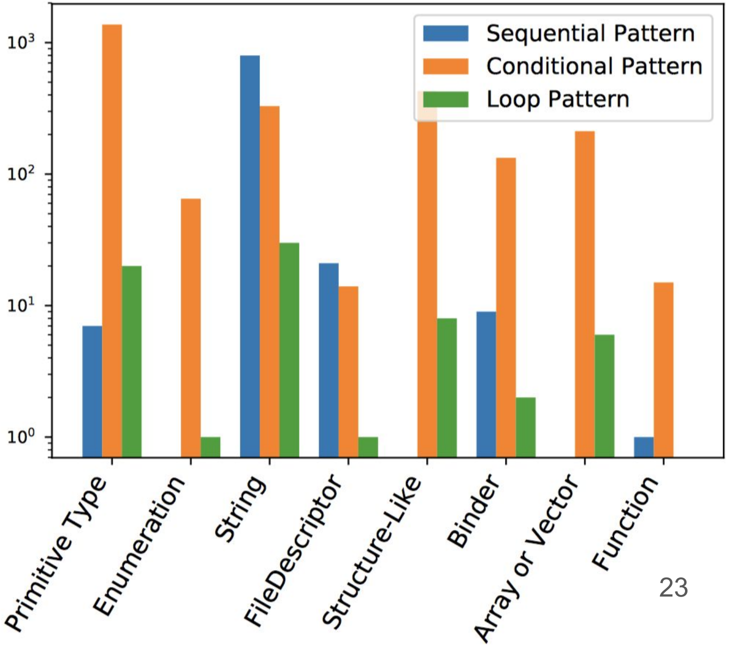
Q1 - Interface Dependency

- ❏ **Interface generation**
  - ❏ e.g., IMemory
- ❏ **Deepest interface**
  - ❏ IMemoryHeap (five-level)
- ❏ **Customized interface**
  - ❏ e.g., IEffectClient



Q2 - Extracted Interface Model Statistics

- Transaction
  - 530 transactions in top-level interfaces
  - 281 transactions in multi-level interfaces
- Variable
  - **Most variables are under constraint(s)**



Q2 - Completeness and Precision

- ❑ Background
  - ❑ There is no ground truth about the interface model
- ❑ Methodology
  - ❑ Randomly select 10 interfaces
  - ❑ Manually check the interface models
- ❑ Result
  - ❑ **Completeness**: all of the transaction codes are recovered
  - ❑ **Precision**: almost all variable patterns, variable names, and variable types are recovered
    - ❑ **The imprecision is mainly due to the complexity of the source code**

Q3 - Vulnerability Discovery

- We intermittently ran FANS for around 30 days
- FANS triggered thousands of crashes
  - **30 vulnerabilities in native programs**
    - **Google has confirmed 20 vulnerabilities**
  - **138 Java exceptions**
- Comparison with BinderCracker
  - BinderCracker found 89 vulnerabilities on Android 5.1 and Android 6.0
  - FANS discovered 168 vulnerabilities on android-9.0.0_r46

Discussion

- ❏ Improve the accuracy of the interface model
- ❏ Integrate coverage into FANS
- ❏ Improve the efficiency of FANS
- ❏ **Extend FANS to other interface-based programs in Android**
  - ❏ e.g., native system services implemented by vendor, java system services

Conclusion

- ❑ A systematical investigation of interface dependency
- ❑ An approach to automatically extract interface model
- ❑ An approach to infer inter-transaction variable dependency
- ❑ A prototype of FANS
  - ❑ 30 vulnerabilities in native programs and 138 Java exceptions
  - ❑ **Source:** https://github.com/iromise/fans

Thanks for listening!
Q & A

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